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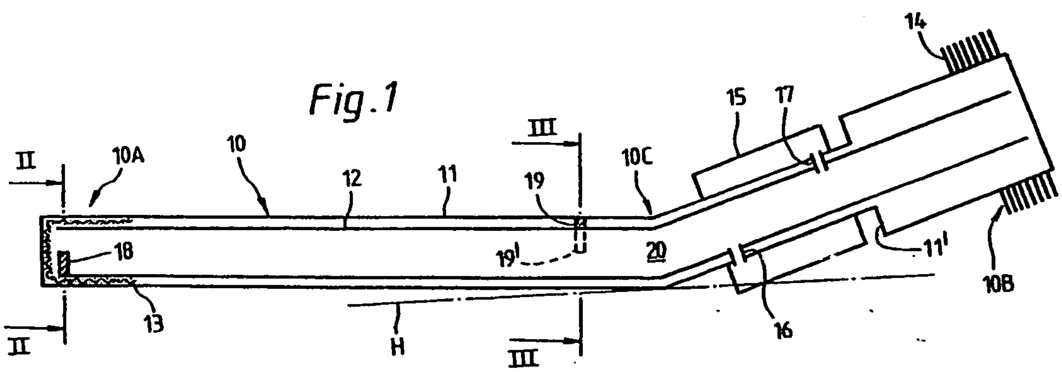
(54) Heat pipes

(57) The starting ability of a heat pipe, having an inner tube (12) separating the vapour-phase path (inside the inner tube) from the liquid-phase return path (annularly outside it), under "negative slope" conditions i.e. with the heat pipe extending (slightly) upwardly towards it heat-absorbing and (10A) is improved by providing not only a bend (10C) so that a part of the heat pipe also extends upwardly towards the heat-releasing end (10B) but also by providing a reservoir (15) communicating, in that part, with the vapour-phase path (instead of the liquid-phase path). A further improvement is then obtained by providing (i) at the heat-absorbing end a weir (18) tending to separate liquid surface levels in the liquid-phase and (flooded) vapour-phase paths and (ii) a saddle-like blocking element (19) blocking the upper part of the annular liquid-phase path near the said bend.

Fig.1



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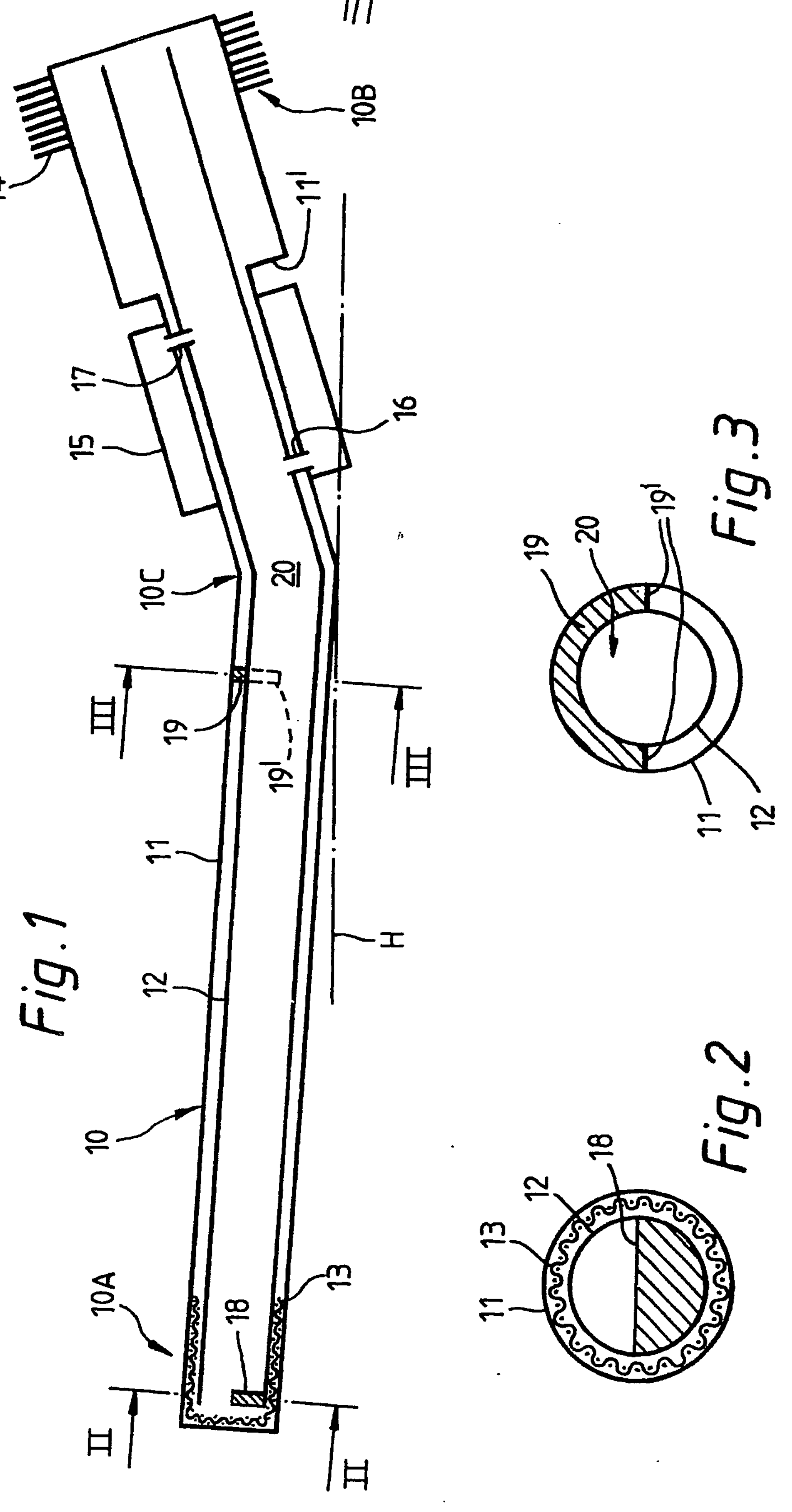

Fig.1
Fig.2
Fig.3
10
10A
10B
10C
11
11'
12
13
14
15
16
17
18
19
19'
20
H
II
III

SPECIFICATION
Heat pipes

This invention relates to heat pipes.

The performance of a conventional wicked heat pipe is quite seriously reduced if the direction in which it is required to convey heat away from a heat source has a downward component in the immediate vicinity of the heat source, i.e. if the heat-absorbing end of the heat pipe is required to operate in what may be called "negative slope" conditions.

It has been proposed, for ensuring that liquid-phase working fluid will be always available at the heat-absorbing end of the heat pipe even under negative-slope conditions, to provide a bend in the heat pipe so that it can be installed with the bend below both the heat-absorbing end and its other, heat-releasing, end and so that, even if the part of the heat pipe between the bend and the heat-absorbing end is unavoidably subject to negative-slope conditions, the heat-releasing end may nevertheless be at a greater height than the heat-absorbing end and working fluid in the liquid-phase (assuming it is present in sufficient quantity) will always be available in adequate quantity at the heat-absorbing end. It has further been proposed, in order to improve the performance of such a heat pipe when operating under negative-slope conditions, to segregate the intended paths of liquid to the heat-absorbing end and of vapour away therefrom, and specifically to provide, within an outer tube (sealed at both ends) of the heat pipe, an open-ended inner tube extending within the outer tube and having its ends opening respectively into the interiors of the respective closed ends of the outer tube, with the interior of the inner tube providing the intended path for vapour from the heat-absorbing end to the heat-releasing end and the generally annular space within the outer tube but outside the inner tube constituting the return path for working fluid in the liquid phase.

A heat pipe in accordance with the above-described proposals can, once started, operate quite efficiently in negative-slope conditions; but in the absence of a sufficient heat supply at its heat-absorbing end to maintain it in operation it is subject to flooding of both the inner and outer tubes at that end with liquid-phase working fluid, and it can be difficult to start again when the supply of heat is resumed. Restarting involves expelling liquid working fluid, by means of working fluid transformed by the heat to the vapour phase, from the intended vapour-phase path, and it has further been proposed, with a view to facilitating this, to provide a reservoir, communicating with the interior of the heat pipe, to accommodate what would otherwise be an excess of liquid working fluid once ordinary operating conditions have been established and the intended vapour-phase path has been cleared of liquid working fluid. It may be remarked, however, that this prior proposal of a reservoir contemplated connecting it to the interior of the outer tube of a heat pipe in which the interior of an inner tube, as mentioned above, would provide the intended vapour-phase path: thus the proposal was to connect the reservoir to the intended liquid-phase path.

Even the above-mentioned proposals for segregation of the vapour-phase and liquid-phase fluid paths and for provision of a liquid-phase reservoir do not lead to a heat pipe which can be relied upon to start dependably under negative-slope conditions; and it is an object of the present invention to provide an improved heat pipe with enhanced starting reliability under negative-slope conditions.

According to one aspect of the invention, a heat pipe comprises a sealed outer tube with a bend intermediate its ends so that its ends, constituting respectively a heat-absorbing and a heat-releasing end, can be higher than the bend, within the outer tube an open-ended inner tube whose ends open into the interiors of, respectively, the heat-absorbing and the heat-releasing ends and which defines and segregates from one another a vapour-phase and a liquid-phase path for working fluid within the heat pipe, and a reservoir connected, between the bend and the heat-releasing end of the heat pipe, with the interior of the heat pipe, wherein the reservoir is connected to a part of the heat pipe interior which is in the vapour-phase path thereof.

Supposing the vapour-phase path to be constituted by the interior of the inner tube, it is the interior of the inner tube with which the reservoir is placed in communication.

According to another feature of the invention, a heat pipe comprising a sealed outer tube with a bend intermediate its ends so that they, constituting respectively a heat-absorbing and a heat-releasing end, can both be higher than the bend, as well as an open-ended inner tube within the outer tube and with its ends opening into the interiors of, respectively, the heat-absorbing and heat-releasing ends thereof, and with the interior of the inner tube constituting a vapour-phase path and a generally annular space between the inner and outer tubes constituting the liquid phase path, is provided, for assisting in starting operation of the heat pipe especially in negative slope conditions, with a blocking element in the annular space between the bend and the heat-absorbing end, which blocking element blocks off an uppermost part of the annular space down to a level below the highest part of the interior of the inner tube at the bend.

Such a blocking element in the liquid-phase path may be provided in a heat pipe according to the invention which also has a reservoir connected to the vapour-phase path; and a heat pipe with such a reservoir, so connected, may also (whether or not such a blocking element is provided in the liquid-phase path) be further provided at its heat-absorbing end with a weir partially closing the corresponding open end of the inner tube.

The invention will be more fully understood from the following description of an embodiment thereof with reference to the accompanying

drawings in which:—

Figure 1 is a schematic longitudinal vertical sectional view of a heat pipe according to the invention;

Figure 2 is a sectional view, on a larger scale, on the line II—II of Figure 1; and

Figure 3 is a sectional view, on the larger scale of Figure 2, on the line III—III of Figure 1.

The illustrated heat pipe 10 comprises an outer tube 11 with sealed ends and, within the outer tube 11 and generally concentric therewith, an open-ended inner tube 12 whose open ends open each into the interior of a respective one of the two closed ends of the tube 11. One end of the heat pipe, the heat-absorbing end 10A, is provided within the tube 11 with a wicked evaporator 13, and the other end, the heat-releasing end 10B, has fins 14 mounted externally on the tube 11 to facilitate the dissipation of heat therefrom. Between its ends 10A and 10B, the heat pipe has a bend 10C at which both the tubes 11 and 12 are bent correspondingly, so that (as illustrated) both parts of the heat pipe may be inclined to the horizontal H and so that, even with the heat-absorbing end 10A subjected to negative-slope conditions, the heat-releasing end 10B may be at a greater height than the heat-absorbing end 10A. It should, perhaps, be stated that in practice the slopes of the parts of the heat pipe might be less than Figure 1 suggests. For example, the distance of the heat-absorbing end 10A from the bend 10C may be three or four metres, and the negative slope conditions may arise only because this part of the heat pipe, though nominally horizontal, has been inaccurately installed (either inadvertently or unavoidably) to such and extent that the end 10A is a few centimetres (say one or two times the diameter of the heat-pipe) higher than the bend 10C.

In these conditions, when the heat pipe is inoperative for lack of heat applied to its end 10A, working fluid in the liquid phase fills, or largely fills, not only the annular space between the tubes 11 and 12 but also the interior of the tube 11, from the bend 10C up towards the end 10A; and the vapour generated at the end 10A when heat is supplied there may (especially if at first it is generated rather slowly) tend to clear liquid-phase fluid (which may be water under sub-atmospheric pressure) preferentially from the annular space rather than from the interior of the tube 12. This tendency may even be aggravated if, as has been proposed, a reservoir is connected to the annular space near the end 10B. If, however, as shown and in accordance with one aspect of the present invention, a reservoir 15 is provided between the bend 10C and the end 10B and in communication not with the annular space but with the interior of the inner tube 11 (this interior constituting the intended path of vapour-phase working fluid from the end 10A to the end 10B), a favourable differential effect is produced for the following reason. A growing bubble of vapour trapped at the end 10A forces liquid-phase working fluid (hereafter called water, for brevity) past the bend 10C and up the interior of the tube 12, and in the annular space between tubes 11 and 12, towards the end 10B, thus increasing the head in both spaces. However, this causes water from the interior of the tube 12 to enter the reservoir 15 through an inlet 16, and the head of water in the tube 12 (and in the reservoir 15) therefore rises less, relative to the head in the annular space, than would be the case in the absence of the reservoir. Therefore water is expelled preferentially from the interior of the tube 12 rather than from the annular space between the tubes 11 and 12, in the vicinity of the end 10A. Conveniently, and as shown, the reservoir 15 is formed as a sleeve or collar surrounding the outer pipe11, and is provided with a vent 17 into the inner tube 12 at a higher level than the water inlet 16, to prevent vapour being trapped in the reservoir.

In order to maximise the beneficial effect of the reservoir 15 in assisting starting, a weir 18 is preferably provided, closing the lower part of the open end of the tube 12 at the end 10A of the heat pipe 10, as shown in Figures 1 and 2. This weir, while not substantially constricting the flow of vapour into the tube 12, has the effect of separating the water levels inside and outside the tube 12 at the earliest possible moment as they are depressed by generated vapour, and thereby of advancing the onset of the differential expulsion rates of water due to the connection of the reservoir 15 to the interior of the tube 12. Once the two water levels are below the top of the weir 18, that inside the tube 12 is depressed more rapidly than that in the annular space outside it.

A further reservoir for water which is in excess once the heat pipe is operating may, as illustrated, be provided by enlargement of the upper end 11' of the outer tube 11 in the vicinity of the end 10B of the heat pipe. It will be appreciated that water spills over into this reservoir only after the reservoir 15 has contributed its favourable differential effect on starting.

Either alone or in combination with the reservoir 15 and its inlet 16 connected to the interior of tube 12, there is provided in accordance with another aspect of the invention a starting aid as shown in Figures 1 and 3. This consists of a blocking element in the form of a saddle 19 situated over the inner tube 12 and blocking the upper part of the annular space between the tubes 11 and 12, near the bend 10C and in the part of the heat pipe between the bend 10C and the heat-absorbing end 10A. The lower margins 19' of the saddle 19 are lower than the uppermost part 20 of the interior of the tube 12 at the bend 10C, even when the part of the heat pipe between the bend 10C and the end 10A is subject to negative slope conditions, and it follows that a vapour bubble of increasing size at the end 10A reaches the bend 10C via the interior of the tube 12 and begins to escape via the part 20 before it has been able to pass the blocking saddle 19 in the annular space between the tubes 11 and 12.

CLAIMS

1. A heat pipe comprising a sealed outer tube with a bend intermediate its ends so that its ends, constituting respectively a heat-absorbing and a heat-releasing end, can both be higher than the bend, within the outer tube an open-ended inner tube whose ends open into the interiors of, respectively, the heat-absorbing and the heat-releasing ends and which defines and segregates from one another an intended vapour-phase path and an intended liquid-phase path for working fluid within the heat pipe, and a reservoir connected, between the bend and the heat-releasing end of the heat pipe, with the inteior of the heat pipe, wherein the reservoir is connected to a part of the heat pipe interior which is in the intended vapour-phase path thereof.

2. A heat pipe as claimed in Claim 1, wherein the reservoir is connected to the interior of the inner tube.

3. A heat pipe as claimed in Claim 2, wherein the reservoir is connected to the interior of the inner tube through two passages at different heights, the higher of such passages serving as a vent through which vapour-phase fluid can escape from the reservoir as liquid-phase fluid enters it through the lower one of the passages, constituting an inlet to the reservoir.

4. A heat pipe as claimed in any of Claims 1 to 3, wherein the reservoir is formed as a sleeve or collar surrounding the outer tube of the heat pipe at a part thereof between the said bend and the heat-releasing end.

5. A heat pipe comprising a sealed outer tube with a bend intermediate its ends so that they, constituting respectively a heat-absorbing and a heat-releasing end, can both be higher than the bend, as well as an open-ended inner tube within the outer tube and with its ends opening into the interiors of, respectively, the heat-absorbing and heat-releasing ends thereof, and with the interior of the inner tube constituting a vapour-phase path and a generally annular space between the inner and outer tubes constituting the liquid-phase path, wherein there is provided, for assisting in starting operation of the heat pipe especially in negative slope conditions, a blocking element in the annular space between the bend and the heat-absorbing end, which blocking element blocks off an uppermost part of the annular space down to a level below the highest part of the interior of the inner tube at the bend.

6. A heat pipe as claimed in Claim 5 and provided with a reservoir connected to the interior of the inner tube and in accordance with Claim 1 and any of Claims 2 to 4.

7. A heat pipe as claimed in any of claims 1 to 6 and provided at its heat-absorbing end with a weir partially closing the corresponding open end of the inner tube.

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